GILDER TECHNOLOGY REPORT

Published jointly by Gilder Publishing and Forbes Magazine www.gildertech.com August 2000/Vol. V No. 8

The Sound of Silence

Summer Review: Part 2

The next decade of wireless history belongs to the progressive, inexorable triumph of CDMA and its inventors at Qualcomm

In the late 1980s, more than ten years ago, Nicholas Negroponte of MIT's Media Lab, made a provocative prophecy. He said that in the future, video and voice would trade media. Video—then mostly broadcast television that chiefly traveled through the air—would move to wires (mostly optical). Voice—then overwhelmingly carried in twisted pair telephone wires—would move to the air.

I immediately endorsed this prediction and dubbed it the "Negroponte Switch." Today it is almost a truism. Despite all the exceptions that prove the rule (satellite TV and broadband wireless Internet), the overwhelming uptake of mobile telephony and cable TV and fiber optics makes the Negroponte Switch one of the best technology predictions ever made.

At the time, Negroponte's call was anything but obvious. Requiring no expensive cables and backhoes, broadcast TV was ubiquitous, one of the most popular and well-established technologies ever launched. Governments heavily supported both air TV and twisted pair telephony and still do today. In the breakup of **AT&T** (T), U.S. regulators assigned free spectrum rights to the Baby Bells, thus assuring that wireless telephony would be promoted as a costly mobile supplement rather than as a rival to wireline telephony.

Mobile phones and tethered video both prevailed because they fit the technology paradigm. What governments did scarcely mattered in the face of the inner logic of video as a broadband spectrum hog that polluted the air but could fly freely through fiber and cable. The errors of regulators could not prevail against the paradigmatic power of microchips to enable mobile telephony better in every important way than analog wireline voice. Listen to the technology and you quickly see that video wants dumb pipes and voice wants clever mobility. What government wants is interesting in the short run but trivial in the long run.

Today governments and gullible telopolies everywhere lust for GSM (Global System Mobile), the government birthed and swaddled choice of the European Commission (EC). A Time Division Multiple Access (TDMA) system, it is maladapted to the Internet's bursty data flows that rarely fit the TDMA timeslots. Beloved of regulated Bellheads, once even endorsed by the U.S. State Department, and flacked and touted regularly in the technologi-

In This Issue:

cally and politically naïve U.S. business press, GSM is the choice of bureaucrats everywhere against the superior U.S. alternative of Code Division Multiple Access (CDMA). Now Japan's **NTT** is buying a GSM spearhead in the US through investment in **SBC-BellSouth's** (SBC) anti-CDMA wireless entity. **Deutche Telekom** is also promoting GSM by buying **Voicestream** (VSTR), the only major U.S. GSM carrier.

For awhile, the chief rival to the world's telopolies, Regional Bells, and European departments of Post and Telecommunications (PTTs) was **WorldCom** (WCOM). It planned to use its Internet prowess to mount an aggressive challenge to national communications monopolies. But as usual governments rallied to the support of the incumbent telco establishment. With the help of clueless U.S. Anti Trusters in Washington, EC regulators first helped block WorldCom's attempt to acquire MCI's Internet unit, on the incredible grounds that the new firm would dominate the Web. The MCI unit went to the U.K.'s Cable & Wireless. Whew! A U.S. Internet monopoly narrowly averted. Then EC bureaucrats collaborated with U.S. kin to thwart WorldCom's bid to buy **Sprint** (FON) and expand **Sprint PCS** (PCS), the leading CDMA carrier. Phew, those evil Internet monopolists foiled again! Now in a new entente of TDMA telopolies, AT&T is rumored to be romancing **British Telecom** (BTY).

CDMA's great feat is that it uses processing to turn noise into silence

All these companies cozening the U.S. market to promote inferior European technology are political entities, either largely government owned (NTT and Deutche Telekom) or are regulated political protectorates dominated by lobbyists rather than engineers (SBC and AT&T). With some 270 million GSM subscribers around the world, GSM is the world's most impressive success of government industrial policy. It recently won major ground in China where CDMA was regarded to be the U.S. government choice after **Qualcomm** (QCOM) executives defensively showered the Democrats with campaign cash and Irwin Jacobs met publicly with Bill Clinton. GSM now leads CDMA in China by some 45 million units to one million units.

On the surface, the picture is grim for the paradigm. Even our own Gilder Forum (www.gildertech.com) is fretful. How then can we be so sure that the next decade of wireless history will be nearly indistinguishable from the last in its salient feature: the progressive, inexorable triumph of CDMA and its inventors and most adept practitioners at Qualcomm?

The argument is necessarily technical. You have to listen to the technology. At its heart you will find the sound of silence. Virtually all communications theory, all contests for mobile superiority, and the final triumph of CDMA revolve around the manipulation of silence: adding it, subtracting it, rearranging, condensing, or expanding it.

It's my party ...

To explain, let us revisit the now legendary cocktail party that Qualcomm founder Irwin Jacobs long ago conceived as an analogy for cellular systems. Several guests have paired off in conversation. But for each listener the sum total of all the other speakers' "transmissions" is mere noise, interfering with his ability to discern the signal sent by the one person to whom he is trying to listen. Struggling to be heard, each speaker talks louder and louder, but that only increases the total noise in the channel—the room—making it even more difficult to hear.

Frantic to save her party, the hostess tries several different solutions. First she disperses her guests into different rooms, one pair to a room. With no noise at all in the room except for its own conversation, each pair converses unimpeded, luxuriating in silence. This is frequency division multiple access, the solution used by analog mobile systems, which dedicates a pair of narrow frequency channels solely to one pair of users in a cell. Since the frequencies cannot be re-used except by users in cells at least two diameters away, the system also invokes *space* division multiplexing.

Alas, while some guests now have a surfeit of silence, many still have none. This is a Manhattan cocktail party, and there are not enough empty rooms (channels) in the apartment for all conversations. A simple spatial division won't do. Taking another stab at the problem, the hostess now places three pairs of conversationalists in each room. All three pairs may converse, but they must take turns. Every 20 seconds, say, one pair gets to talk, the other two must be silent. Adapting to the problem, the guests find that, when it is their turn, they tend to talk faster than usual. And while waiting, they search for economical turns of phrase, to encode more meaning in less transmission time. This is time division multiple access (TDMA), made possible by digitizing the voice signals so we can send them in rapid bursts, combined with some speech compression codes to save bits, and it triples the number of conversations the hostess can accommodate.

... I can talk if I want to

But wireless is a paradigm party, the party of the decade. Guests continue to throng in at a rate of millions a week. Suddenly the solution dawns on the hostess. Her party is ever so cosmopolitan, with Japanese, Koreans, Indians, and polyglot Chinese and Europeans. So she asks everyone to return to the main room, and speak as softly as they can manage, but each pair in a different language. *Mirabile dictu*, everyone can hear and understand the signal meant for them. A little better if a few guests leave; a little worse if a few more show up, but satisfactorily in any event. This of course is code division multiple access (CDMA).

Adding silence, taking away noise, the solutions progress on a continuum from the purely physical to the predominantly logical. In the first, analog solution our only resources are physical—separate the speakers by space. In the TDMA solution we employ two physical dimensions, and build our isolation chamber out of both space and time. TDMA plies logic as well, compressing communications to fit better into those slots. But only the final solution is predominantly logical—assign each speaker a different language, or code. Coding the messages into different languages provides virtual silence, since listeners easily filter out the sounds of languages they do not understand, readily identifying them as "noise" rather than signal.

Adding silence in this way is only part of the story. Also crucial is silence removal. Although silence is indepensable to communications, it is also an arrant waste of bandwidth.

In the core of the Telecosm, defined by the optical network, such waste reveals correct priorities: spend abundant bandwidth to save expensive processing. Thus optical switches—which like mirrors merely steer or redirect physical beams of light—drive out electronic switches, which laboriously and expensively process the underlying packets.

Wireless, though, is an environment of bandwidth constraint rather than bandwidth abundance. Here the logical still trumps the physical, smart systems are better than dumb ones. Because we cannot expand the physical resource, as we can in fiber optics simply by laying more fiber, the wireless paradigm favors solutions that use logic—manifested in electronic processing—most aggressively and adeptly. In short, the winning technology will exploit most effectively the old microcosmic abundance defined by Moore's Law. In the Telecosm, the Moore's Law abundance is found less in **Intel** (INTC) microprocessors fetching instructions and data from memories than in Digital Signal Processors (DSPs) from companies such as **Texas Instruments** (TXN). These devices handle real time streams from analog-to-digital converters made by companies such as **Analog Devices** (ADI) and **National Semiconductor** (NSM).

After considering the investment implications of this part of the paradigm, we return to the party. Consider again our hostess. Her first solution—each conversational pair got its own room—wasted silence. With each speaker occupying an entire channel, much of what flows through—some 65 percent in fact—is silence. In typical phone conversations, each speaker talks about 35 percent of the time, with both parties silent about 30 percent of the time. And because the analog signals in the communication "look" just like the sound waves they imitate, they cannot be compressed or accelerated.

Sorting silence

The TDMA solution—three pairs of conversationalists in each room—is digital. But for all its digital compression, sampling, and rearranging, TDMA does not directly address the wasted silence problem. Dedicating rigid time slots to each user, TDMA neither knows nor cares whether the user is making good use of allocated bandwidth. Whether shouting for 911 or whistling Dixie, 65 percent of the time users are dead silent and so are their allocated channels. Over-provisioning silence and wasting bandwidth to save processing, TDMA represents at best a form of rationing that uses relatively mindless rules to allocate silence, and thus inevitably wastes it.

TDMA wastes silence, CDMA spends logical MIPS to save and manufacture silence

Where TDMA wastes silence, CDMA spends logical MIPS to both save and manufacture silence. Under the guidance of Qualcomm cofounder Andrew Viterbi, who created crucial coding algorithms used in nearly all digital communications systems, Qualcomm developed the variable rate vocoder. In TDMA or CDMA a vocoder condenses the 64,000 kbps digitized version of your speech down to between 8 and 13 kbps. But in pauses or silence, CDMA's variable rate vocoder will output at as little as one-eighth of the full rate. The momentarily silent user opens up space in the channel for other conversations. The variable vocoder alone accounts for a 250 percent increase in the capacity of a CDMA cell, but it would be pointless in a TDMA system, which shares time but cannot share silence.

Thanks to the law of large numbers in CDMA, the salvaged silence is spread out across the shared 1.25 megahertz channel in a variant of statistical multiplexing, the basic economizing principle behind any shared channel, like an Ethernet or the Internet. As with an Ethernet, there is only a "soft" limit on the number of users: adding one more will increase the interference in the channel only marginally. Our hostess need not panic if a late guest shows up at the door.

Even more auspicious for CDMA in the coming era of the wireless web, the hostess need not despair even if scores of guests decide to deliver speeches with Powerpoint slides or transmit lengthy Postscript files. Because the CDMA system spreads all the data across all the available spectrum all the time, it can accommodate the bursty bitstreams characteristic of the Internet. Rather than bandwidth confined to an irretrievable series of narrowband time slots, CDMA can offer bandwidth-on-demand.

Thus CDMA exploits processing to add silence where it is needed and take away where it would be wasted. But CDMA's greatest feat and the essence of the system is that it uses processing to turn noise itself into silence.

In any communication channel all the transmission power ends up either as noise or signal, and some of it ends up as both, because even a well shaped signal is noise to a user trying to receive a different signal. In TDMA, there are only two possible fixes. Raise the power of the transmission, thus making it more likely that the bits will be discernible through the noise. But any additional power will show up as additional noise on adjacent channels, confronting them with the same choice. (The guests at the cocktail party have started to shout.) Or the sender can add more bits—e.g. in the form of more elaborate error correction—but this will decrease the information rate of the channel. (The guests at the party have started to repeat themselves.)

CDMA soaks up all this overflow of noise and bits with DSP MOPS (millions of operations per second). The CDMA transmitter first multiplies the information bits by a pseudo-random noise code and then spreads the resulting apparently randomized signal across a slice of spectrum more than 100 times the bandwidth of the original signal. Like a platoon spread out to avoid death from a single grenade, the spread signal cannot be wiped out by noise in any narrow portion of the channel.

With the lonely and inexplicable exception of AT&T's Edge, every seriously proposed 3G system is based on CDMA

When the signal is spread by a factor of more than 100, its energy is necessarily spread as well…*and so is the energy of the other users of the same spectrum*. Collectively the signals of dozens of users have acquired the essential characteristics of, if not quite white then "gray" Gaussian noise. The result is scores of decibels of "processing gain": an apparently magical power of hearing a soft sound above a much louder one of similar pitch. Abandoning the attempt to power past competing users, CDMA lowers the energy of all signals to the minimum needed to reach the receiver. Because the receiver has the matching noise code—which is inverted to delete the noise through destructive interference—the message can be extracted from the background drone. What would have been a cacophony of competing voices now appears as a low murmur, like the celestial hum of a Gregorian choir against which the soloist stands in vivid relief.

Transforming noise into a form of silence, CDMA also redeems "multipath" signals arriving by different routes, and thus at slightly different times. Normally multipath is irredeemable noise to a time slotted system, but CDMA uses an early invention of optical sage Paul Green, the "rake receiver," to combine the three best multipath signals into an amplified CDMA stream. On the sector edges, the rake receiver even permits the soft shifting of users from a crowded cell (route 101 at rush hour) to an underused neighbor (Los Altos Hills)—thus effectively shrinking and expanding cells in response to the movement of traffic.

By substituting the transmission of logic for the transmission of power and by binding up the energy that remains into a wider and more redundant logical web, CDMA ensures that a greater portion of that energy is actually used to deliver information, the definition of spectral efficiency.

CDMA envy

Every other wireless system is now emulating these CDMA devices, doing more processing for better power control and more bits per hertz (an EDGE effort) or more processing to do magic with antennas (an NTT DoCoMo focus) or more processing for better error correction and turbo codes (CDMA 2000 uses them as a critical ingredient in its doubling of voice capacity). Because all of these technologies are being advanced by ingenious engineers, at any given moment performance data will incite a flurry of claims about the latest heroic tweak, or the newest, best, vaporware ever, or never. This is a trillion dollar argument and the room can get very noisy.

The value of a paradigm is to keep one from losing the signal amidst the competitive noises. And in wireless the paradigm is "more logic and less power." However noisy the argument, CDMA's triumph is readily discernable in the simple fact that for the Third Generation (3G) systems of the Internet, TDMA, which fails the paradigmatic test, has virtually abandoned the field. With the lonely and inexplicable exception of AT&T's EDGE, every seriously proposed 3G system is based on CDMA.

The evolving WCDMA standard is being written in an apparent attempt to be as different from Qualcomm's CDMA as possible, while still deriving its advantages, so the Europeans could retain or the Japanese attain world leadership in wireless. The Japanese government in particular has been pressing NTT DoCoMo to ensure the global 3G standard would come from Japan. To that end, NTT has been developing WCDMA since the early 1990s.

In theory WCDMA enhances the advantages of CDMA by expanding fourfold the spread (or so called "chipping rate") in its "spread spectrum." Thus, each signal is spread more widely by a higher chipping rate, each bit is lower power, rendering the resulting background noise even more Gaussian (a smoother more random appearing hum against which to search out the signal). Since more users are sharing a single channel, the statistical multiplexing advantages of variable rate vocoding are enhanced.

The law of large numbers, however, suggests that at some point "large" becomes "too large" and returns beyond this point diminish. Before settling on a 1.25 MHz spread almost a decade ago, Qualcomm sage Klein Gilhousen studied a range of spectrum widths and chipping rates for expanding the signal. He found that an eightfold increase, from a chipping rate of 16 to 128, produced a 20 percentage point increase in spectral efficiency. By increasing the rate another eightfold to 1024 over 10 MHz, however, the WCDMA proposal of the time would yield less than half that increase, about 9 percent. The current WCDMA proposal would yield about 6 percent greater spectral efficiency.

In the real world of limited spectrum, the right channel width must reconcile the advantages of channel spread with the need for channel flexibility. More channels are easier to swap from voice to data and back again to accommodate shifting demand during the course of the day or to offer bandwidth on demand.

While gaining paltry and diminishing returns in spectral efficiency, the wider spread incurs real and rising costs in chip set complexity and handset power. Operating across a wider spectrum, a WCDMA rake receiver must process three times as many signal elements in the 156 microseconds available, requiring more rake components, each operating three times as fast. The result is more complex and expensive chips, more silicon area, more power consumption, and ultimately, perhaps, lower performance.

Nevertheless, in principle, WCDMA has at least debatable merits. In practice, the standards process has become an exercise in product design by committee, with each member desperate to inseminate the elephant with his own intellectual property, producing the usual lumpy patchwork of a patent bearing camel. Extending the theory that if CDMA is good, more is better, WCDMA adjusts power levels 1600 times a second rather than CDMA's 800. But power control bits, because they cannot be coded for error protection (there is no time to decode them) must be sent at much higher power than the rest of the signal, boosting interference, and sweeping the design well beyond the point of diminishing returns.

Bad as this all sounds, NTT DoCoMo is pledged to have a nominal WCDMA network up and running somewhere by late next spring, though at the moment it promises only 64 kbps data, the rate of Qualcomm's IS95B, a 2G system available in Japan today from DDI-IDO. Qualcomm will have a WCDMA demo-chip available by the end of this year, produced in consultation with one or two likely future customers, such as Japan Phone.

Happily, the standard's worst mistakes are unlikely to survive. The Japanese already plan to ignore such "features" as the "compressed mode" for GSM compatibility. According to John Brewer, of Vincio Group, the Europeans are unlikely to do WCDMA at all: "WCDMA deployment dates stretch out by a year every six months." CDMA is hard. Stonewalled out of effective participation in WCDMA standards meetings so far, expect to see Qualcomm's influence over the evolving standard grow. The spin-off of the chip company should improve matters even further as it separates Qualcomm the supportive vendor from Qualcomm the royalty collector.

For similar reasons, expect current Korean CDMA One operators to stay with CDMA 2000 and HDR rather than move to WCDMA, despite all blandishments of NTT. WCDMA is going to have a long gestation and a painful delivery. CDMA 2000 is already here.

Neither the first phase of CDMA 2000, which will provide data rates at up to 144 kbps, plus doubling voice capacity, nor the second phase which incorporates HDR with data up to 2.4 Mbps (expect announcements over the next year pushing that number up several fold) require dramatic upgrades to the network. As one Qualcomm engineer summed it up: the same hardware, the same waveform, the same channels, the same cell geometries, pin compatible chips, and forward and backward compatible handsets.

QCOM's transition to 3G

The new mobile chip, the MSM 5000 series, available to operators in sample quantities this month, brings capacity and features that will be particularly beloved by the folks at Wingcast, the **Ford** (F)-Qualcomm joint venture. It plans navigational, safety, security, scheduling, and even entertainment services in your car. Included are improved GPS reception, enhanced graphics support for, e.g. your Wingcast Maps, MP3 for music by phone, Bluetooth, and enhanced voice recognition for hands-free operation to limit what our friend Mark Mills calls unplanned car-telephone pole interactions.

Part of Qualcomm's strategy for seamless transition to 3G, the added features should prompt most handset manufacturers to use the new chip as soon as it ships this year. Thus, when CDMA 2000 becomes generally available, millions of phones equipped to benefit will already be in subscriber's hands.

Spinco will separate Qualcomm the supportive vendor from Qualcomm the royalty collector

The HDR chip strategy will be similar. The current sample chip—the first true 3G chip—will never be released. Instead the HDR design will be incorporated on the next generation of 2000 chips, once again pin compatible with previous versions, and once again significantly before HDR services are offered nationwide.

Optimized for Internet Protocols, HDR is a pure CDMA system on the reverse link (mobile phone to base station). The forward link, where data rates up to 2.4 Mbps kick in, adds a dynamic time division element that stands static TDMA on its head. Every 1.67 milliseconds, using CDMA's power control and channel monitoring abilities, HDR determines which current mobile user can get the best reception from the base station and uses all available capacity, up to 2.4 Mbps in current versions, to execute that user's download request. Because of the volatility of mobile reception, the best and worst users may swap status in milliseconds. By favoring the best user most of the time, average throughput across the channel will be much higher than if the system rotated, TDMA like, through rigid pre-assigned time slots. By clearing the current best user's downloads out of the queue ASAP, everyone's waits are reduced. The net result, is to ramp up effective average throughput which is far more important than the theoretical maximums usually cited when comparing 3G data systems.

Both GPRS, the generation 2.5 transition for GSM networks on the way to WCDMA, and EDGE, the 3G data solution for some TDMA networks, will be hard pressed to compete with the CDMA 2000/HDR combination.

GPRS claims to offer data rates up to 115 kbps. But this requires bonding together eight adjacent power hungry (as much as 20x the power consumption of CDMA) channels, and pumping as much as 5W through the handset, not likely to have positive effects on battery life, the phone, or the facial complexion of the user. In practice GPRS data rates will probably top out at about 56k, and typically function at half or a quarter that rate.

Wingcast could offer universal and robust connectivity with Globalstar. This could be a breakthrough opportunity for G*

Promised for sometime in 2002 to compete with HDR, EDGE now also promises an enhanced version that will go beyond the originally specified 384 kbps all the way to some vaporous megabits. But the strain shows. Every theoretical enhancement to a TDMA system—including smart antennas, dynamic channel control, even significantly upgraded power control—is being conjured on its behalf. But every proposed tweak is equally available to CDMA, and confers no competitive advantage. Edge will remain a bandwidth wasting technology that may well not ever be built (although AT&T may cobble the camel together and call it an Angel).

Mustang Globalstar

At the moment, the folks at Wingcast, Qualcomm's joint venture with Ford, aren't quite sure how **Globalstar** (GSTRF) fits into their picture. But the big plays for Wingcast are safety (as in links to emergency services if you are in an accident), security, and navigation, none of which make much sense if you lose them when you drive out of cell range. Minimalist versions of all three can be done with satellite based short messaging, plus GPS, all platformed on a couple of geosynchronous satellites hanging about at 23,000 miles up, i.e. not Globalstar.

But minimalist is not what Wingcast has in mind. At least for the high end customer they are planning to build in robust Internet access (Globalstar can do up to 200 kbps currently). They envisage voice through a proprietary network with, e.g., live operators to talk you through a life threatening accident, and automatic updating of schedule, directions, travel info, and the like. All will be web based so it will follow you around from the car to your PDA, laptop and desk top. All this universal and robust connectivity is what Wingcast could offer that GM's OnStar service cannot as yet. This could and should be a breakthrough opportunity.

Even more than the Wingcast possibilities, the deal with In-Flight Network, IFN, to deliver e-mail, Internet access, and real time entertainment to airline passengers at 200 kbps by early 2001, confirms that Globalstar represents not just a phone company but is an adaptable communications platform, with business models it hasn't even thought of yet. The IFN upgrade was successfully tested in June. Like the turn on of data services to North American subscribers, also at 200 kbps and coming this fall, it required only a software adjustment.

In-Flight Network estimates there are 25-45 million frequent flyers of which 5-7 million are already regular Internet/e-mail users. Globalstar sells capacity to IFN at approximately the same 45 cents a minute the other resellers pay.

By the end of Q200 Globalstar had seventeen gateways in revenue service in thirty-nine countries. The complete network, comprising thirty-eight gateways in over one hundred twenty countries is promised by Q1 2001. The Puerto Rican gateway, promised for July, is late. But, the Caribbean has coverage by virtue of another ground based upgrade, derived from bordering gateways in Texas, Mexico, Nicaragua, and Venezuela.

The $.45 per minute wholesale price, playing out to roughly $1.50 retail, has lots of room to fall. ING Barings analysis says Globalstar can break even at less than $.15 per minute. Resellers have been offering promotional plans as low a $.49 per minute, and phones for as low as $699.

By the end of Q2, subscribers still numbered only 13,000, and average weekly mobile minutes of use (MOU) had climbed from 41,000 in May and 76,000 in June to 118,000 by the second week in July. MOUs for fixed phones are still unclear because the large number of test phones in use during the rollout skews the numbers.

"Vertical markets," of corporate and government buyers are opening up. Globalstar has been named an approved vendor by the United States General Services Administration (GSA), which overseas purchasing for all branches of the federal government. The Canadian federal government and seven of its provincial governments, Mexico, Brazil, and several European countries are using Globalstar phones for law enforcement, armed services, search and rescue and transmitting election returns. The National Organization of Gas Expenders (ONEXPO) will install satellite-based data and voice communications across its network of 4500 gas stations in Mexico. The SAT550X Marine Terminal for sea-going vessels made its debut at the Posidonia International Shipping Exhibition.

While voice quality continues to get rave reviews, the specter of Iridium continues to depress the share price. But it is ridiculous to compare Globalstar's elegant and cost effective system with Iridium, an expensive kludge that could not be upgraded without replacing the satellites.

Eighty-five percent of the world's landmass is not served by cellular (including the GTR staff residing in the Berkshires). With three million customers, on the Baring analysis, Globalstar could earn EBITDA of $1.2 billion on revenues of just $1.5 billion, the sort of margins that, well, cause people to launch rockets.

To comprehend the full promise of these CDMA companies, however, you have to focus again on the Negroponte Switch. Now amplified with wireless data, the Switch will eventually take the awesome 300 million subscriber GSM army expected by the end of this year and reduce it to less than 10 percent of the total global wireless market. That larger market will be dominated by Internet access, mobile and fixed, using a huge variety of devices, from notebook computers and personal digital assistants to a cornucopia of varied cellular phones. Utterly unlike fiber optics, wireless is inexorably an arena of bandwidth scarcity. The winners will be companies that can most efficiently manufacture silence as a backdrop for the bursty broadband floods of bits. The best situated of all those companies is still Qualcomm.

FYI: WFI

Of course, the CDMA profile of risk and reward offered by our favorites Qualcomm and Globalstar will not suit all subscribers. Attempting to reduce exposure to political spikes and marketing noise, many will attempt to spread their spectrum of wireless investments across such technologies as LMDS (Local Multipoint Distribution System), MMDS (Microwave Multipoint Distribution System), **Metricom**'s (MCOM) frequency hopping "Ricochet", wireless optics, Bluetooth, and the world's thousands of cellular and PCS service vendors.

On the other hand, subscribers can choose the one company whose capabilities play across the entire range of these technologies, from Ricochet and LMDS to 2.5 G and 3G, from wireless web to wireless optics, without losing focus on a sharply conceived and concerted business strategy. That company is **Wireless Facilities, Inc.** (WFII) of San Diego. With more than 1000 wireless professionals with experience throughout the pinnacles of the industry, from Bell Labs to Bell South, WFI provides outsourced services covering the gamut of wireless functions. At the outset of a project, it offers technology analysis and schematics, site acquisition and preparation. Then it plans, designs, installs, manages, and maintains wireless networks of all kinds.

Among WFI customers were all the first 12 American deployers of PCS services, including both our acclaimed Sprint PCS and AT&T partners **TeleCorp PCS** (TLCP) and **Triton PCS** (TPCS). WFI's domestic assignments span the field of companies and technologies from cellular leaders **AirTouch** (VOD) and **Nextel** (NXTL) to LMDS pioneer **ART** (ARTT) of Seattle and unlicenced spectrum player Metricom—with an optical pretender in **Air Fiber** of San Diego. With overseas ventures in Mexico, Poland, India, Nigeria, Singapore, Australia, and the UK, to name a few, WFI services the globe.

Although WFI is standards agnostic, and cherishes a technically compromising relationship with **AT&T Wireless** (AWE), its analysts calculate that current 2G CDMA systems are at least four times as efficient as TDMA and GSM systems in the voice oriented metric of Erlangs per cell per megahertz of spectrum. With a hugely growing backlog of projects, and a strategy of enabling and accelerating the Negroponte Switch, WFI is situated at the heart of the wireless new world. As the company concentrates increasingly on advanced data projects, WFI will necessarily have to become chiefly a CDMA specialist. Anticipating this paradigmatic destiny—and appreciating its current promise—we promote WFI to our Telecosm list.

George Gilder & Richard Vigilante
August 21, 2000

The Mirror Image advantage

Like every technology star that suffers a collapse of its stock price, **Mirror Image** (XLA) is now beset with class action shakedown suits. The complaint—that the company falsely touted its storewidth technology—has already been refuted by events. On April 26, the leading Internet hosting company, Exodus, adopted the Mirror Image system and claimed a 15 percent stake in the company for $638 million, giving Mirror Image $75 million in cash and two percent of Exodus. Also a partner is Hewlett Packard, which invested $52 million in the company and is driving the buildout of its technology. Other collaborators in the "scam" include Lucent's optical switching division and the storewidth division of Compaq.

Mirror Image represents a new paradigm in storewidth. Competitive content accelerators such as Adero and Akamai, give their own content vending customers an advantage over non-customers by dispersing content through thousands of servers. As a result, the more customers they get the less the advantage. Already serving some 55 Internet Service Providers at the National Access Point (NAP) level, Mirror Image improves the performance of the entire net. Gilder Publishing is one of many companies now beta testing MII content distribution services (publicly available in September). A tire manufacturer faced with a firestorm of recall inquiries turned to Mirror Image to solve its problem by quickly connecting its site to the closest Content Access Point (CAP). Although MII does not activate a CAP until they can connect all major carriers in a region, 17 CAPs are now up and running, each housing $2 million worth of Cisco, HP, Sun, Oracle, and Veritas gear. By 2001, MII plans to have 32 CAPs installed, once again exceeding all early promises of its management to the GTR.

Mary Collins and George Gilder

TELECOSM TECHNOLOGIES

ASCENDANT TECHNOLOGY	COMPANY (SYMBOL)	REFERENCE DATE	/ PRICE	JULY '00: MONTH END	52 WEEK RANGE	MARKET CAP
WINGS OF LIGHT						
Wireless, Fiber Optic Telecom Chips, Equipment, Systems	Lucent (LU)	11/7/96	11 25/32	43 3/4	39 11/16 - 84 3/16	146.1B
Wave Division Multiplexing (WDM) Systems, Components	Ciena (CIEN)	10/9/98	8 9/16	142 1/8	29 3/8 - 189	20.1B
Wireless, Fiber Optic, Cable Equipment, Systems	Nortel (NT)	11/3/97	11 1/2	74 1/4	19 7/8 - 89	215.2B
Optical Fiber, Photonic Components	Corning (GLW)	5/1/98	40 15/16	235	62 5/8 - 289 15/16	65.3B
Wave Division Multiplexing (WDM) Components	JDS Uniphase (JDSU)	6/27/97	3 5/8	118 1/8	23 5/16 - 153 3/8	92.4B
Adaptive Photonic Processors	Avanex (AVNX)	3/31/00	151 3/4	126 15/16	47 3/8 - 273 1/2	8.1B
All-Optical Cross-Connects	Agilent (A)	4/28/00	88 5/8	40 3/4	38 3/16 - 162	18.4B
THE LONGEST MILE						
Cable Modem Chipsets	Broadcom (BRCM)	4/17/98	6*	224 1/4	51 9/16 - 261 9/16	48.2B
S-CDMA Cable Modems	Terayon (TERN)	12/3/98	15 13/16	51	15 5/8 - 142 5/8	3.2B
Linear CDMA Power Amplifiers, Cable Modems	Conexant (CNXT)	3/31/99	13 27/32	30 1/2	26 1/2 - 132 1/2	6.9B
THE TETHERLESS TELECOSM						
Satellite Technology	Loral (LOR)	7/30/99	18 7/8	5 1/4	5 - 25 3/4	1.6B
Low Earth Orbit Satellite (LEOS) Wireless Transmission	Globalstar (GSTRF)	8/29/96	11 7/8	7 9/16	5 13/16 - 53 3/4	732.9M
Code Division Multiple Access (CDMA) Chips, Phones	Qualcomm (QCOM)	7/19/96	4 3/4	64 15/16	38 1/16 - 200	48.4B
Nationwide CDMA Wireless Network	Sprint (PCS)	12/3/98	7 3/16 *	55 1/4	28 5/16 - 66 15/16	50.6B
CDMA Handsets and Broadband Innovations	Motorola (MOT)	2/29/00	56 53/64	33 1/4	27 5/16 - 61 1/2	72.5B
Wireless System Construction and Management	Wireless Facilities (WFII)	7/31/00	63 5/8	63 5/8	15 - 163 1/2	2.7B
THE GLOBAL NETWORK						
Broadband Fiber Network	Level 3 (LVLT)	4/3/98	31 1/4	68 7/16	49 7/8 - 132 1/4	25.1B
Broadband Fiber Network	Metromedia (MFNX)	9/30/99	12 1/4	35 1/8	11 1/8 - 51 7/8	19.3B
Submarine Fiber Optic Network	Global Crossing (GBLX)	10/30/98	14 13/16	24 5/16	20 1/4 - 61 13/16	19.9B
Broadband Fiber Network	Northeast Optic (NOPT)	6/30/99	15 1/16	42 3/16	27 7/8 - 159	702.7M
Telecommunications Networks, Internet Access	WorldCom (WCOM)	8/29/97	19 61/64	39 3/16	32 9/16 - 61 5/16	112.2B
CACHE AND CARRY						
Directory, Network Storage	Novell (NOVL)	11/30/99	19 1/2	9 15/32	7 7/8 - 44 9/16	3.1B
Java Programming Language, Internet Servers	Sun Microsystems (SUNW)	8/13/96	13 3/4	105 7/16	36 1/8 - 115 3/16	167.7B
Network Storage and Caching Solutions	Mirror Image (XLA)	1/31/00	29	15 1/8	1 - 112 1/2	1.6B
Disruptive Storewidth Appliances	Procom (PRCM)	5/31/00	25	43 1/2	5 5/8 - 89 3/4	496.6M
Remote Storewidth Services	Storage Networks (STOR)	5/31/00	27*	109 1/8	82 - 154 1/4	9.7B
THE MICROCOSM						
Analog, Digital, and Mixed Signal Processors	Analog Devices (ADI)	7/31/97	11 3/16	66 5/8	22 - 100	23.7B
Silicon Germanium (SiGe) Based Photonic Devices	Applied Micro Circuits (AMCC)	7/31/98	5 43/64	149 1/4	21 3/16 - 174	18.6B
Programming Logic, SiGe, Single-Chip Systems	Atmel (ATML)	4/3/98	8 27/32	29 15/16	15 1/16 - 61 3/8	6.6B
Digital Video Codes	C-Cube (CUBE)	4/25/97	23	19 15/16	14 1/4 - 106 1/4	947.3M
Single-Chip ASIC Systems, CDMA Chip Sets	LSI Logic (LSI)	7/31/97	15 3/4	34	21 9/16 - 90 3/8	10.4B
Single-Chip Systems, Silicon Germanium (SiGe) Chips	National Semiconductor (NSM)	7/31/97	31 1/2	36 1/8	23 1/2 - 85 15/16	6.4B
Analog, Digital, and Mixed Signal Processors, Micromirrors	Texas Instruments (TXN)	11/7/96	5 15/16	59 1/2	35 5/8 - 99 3/4	97.6B
Field Programmable Gate Arrays (FPGAs)	Xilinx (XLNX)	10/25/96	8 7/32	75 3/16	30 1/2 - 98 5/16	24.5B

ADDED TO THE LIST: WIRELESS FACILITIES

* INITIAL PUBLIC OFFERING

NOTE: The Telecosm Table is not a model portfolio. It is a list of technologies in the Gilder Paradigm and of companies that lead in their application. Companies appear on this list only for their technology leadership, without consideration of their current share price or the appropriate timing of an investment decision. The presence of a company on the list is not a recommendation to buy shares at the current price. Reference Price is the company's closing share price on the Reference Date, the day the company was added to the table, typically the last trading day of the month prior to publication. Mr. Gilder and other GTR staff may hold positions in some or all of the stocks listed.

Gilder Technology Report ***Published by Gilder Publishing and Forbes Inc.***

Monument Mills • PO Box 660 • Housatonic, MA 01236

Tel: (413)274-3050 • Fax: (413)274-3031 • Email: info@gildertech.com

EDITOR: George Gilder

PUBLISHER: Richard Vigilante

TECHNOLOGY ANALYSTS: Charles Burger, Mary Collins, Bret Swanson

MANAGING EDITOR: Debi Kennedy

DESIGNER: Julie Ward

SUBSCRIPTION DIRECTOR: Rosaline Fernandes

GENERAL MANAGER, GILDERTECH.COM: David S. Dortman

PRESIDENT: Mark T. Ziebarth